

ELECTRONIC FUNDAMENTALS

THEORY LESSON 4

ELECTRON THEORY AND CURRENT

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RCA INSTITUTES, INC.

**A SERVICE OF RADIO CORPORATION OF AMERICA
HOME STUDY SCHOOL**

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Theory Lesson 4

INTRODUCTION

We cannot see, hear, feel, taste, or smell electricity, yet we know that it exists because of some of the effects it produces. When we turn on an electric lamp, electricity must be present because we see light. If we connect an electric iron to an electric outlet, electricity must be flowing because the iron gets hot. Electricity flowing through liquids has a chemical effect; this effect is used in electroplating metals. When you touch the terminals of an electric power source, no one has to tell you that electricity is present — the shock is proof positive!

Although we use electricity to do many things and can measure it with accuracy, we have no exact knowledge of its nature. Many theories have been developed to explain what happens in electric circuits. One theory, while it does not explain everything, is generally accepted. It is called the *electron theory*.

4-1. STRUCTURE OF MATTER

Before studying the electron theory, we must know something of the structure of matter. All substances are composed of *elements*. An element is a substance that cannot be broken into simpler parts by ordinary chemical means. There are 92 natural elements. In addition, there are several man-made elements, which are produced in atomic-energy research. All things, animal, vegetable, and mineral — even the air we breathe — are made up of these elements.

For that reason, they are sometimes called the "building blocks of the universe". Some substances, such as copper, lead, iron, and oxygen are pure elements. Other sub-

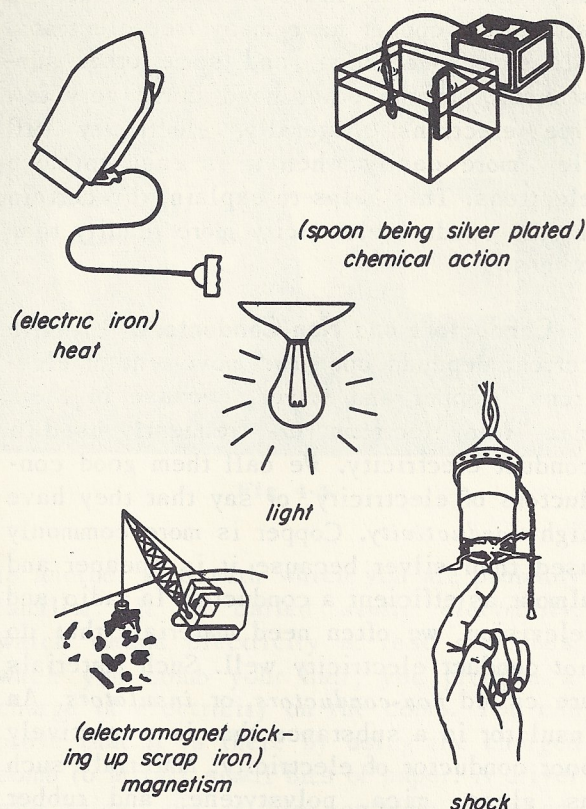
stances, such as water, table salt, and wood, are made up of two or more elements. We call these substances *compounds*. The smallest divisible particle of a compound is called a *molecule*. Molecules may be broken up into the smallest bits of matter of which their elements are composed — atoms. The molecule and the atom are so very small that they cannot be seen, even under the strongest microscope.

4-2. ELECTRON THEORY OF MATTER

Most modern scientists believe that atoms are made up of positively and negatively charged particles. Negative particles are called *electrons*, and positive particles are called *protons*. We may think of all the atoms of any one element, in the normal neutral state, as being exactly alike in the number of electrons and protons they contain. Atoms of *different* elements differ only in the number of electrons and protons they contain. For instance, an atom of hydrogen contains one electron and one proton, while an atom of oxygen contains eight electrons and eight protons.

Atoms have been compared to solar systems, like the system including our sun and its planets. The central part of each atom, called the *nucleus*, contains all the protons. Whirling around the nucleus, very much like the planets around the sun, are the electrons. The negative charge of each electron is exactly equal to the positive charge of each proton. Thus, the total positive charge of an atom will, under ordinary conditions, equal the total negative charge.

Figure 4-2a is a drawing of the hydrogen atom. In the center is the nucleus with its one proton. Traveling in its orbit around the nucleus is one electron. While the proton and



Five ways in which electricity is known to us.

Fig. 4-1

the electron are the same size, the proton is more than 1800 times as heavy as the electron. Figure 4-2b shows an atom of helium, with two electrons in their orbits around the nucleus. In the nucleus are two protons and two neutrons. The neutron is about the same size and weight as a proton, but is neutral in charge. Scientists believe that a neutron is formed by an electron and a proton combining in the nucleus. Because the individual charges of the proton and electron are equal and opposite, they neutralize each other.

The atomic weight of an atom is determined by the weight of the protons and neutrons in the nucleus. (Neutrons are not important in the study of radio and television, but are very important in the study of atomic energy.) Notice that the orbits of the electrons in the helium atom are of the same size. Now consider the drawing of the beryllium atom, in Fig. 4-2c. Note that the nucleus contains four protons and five

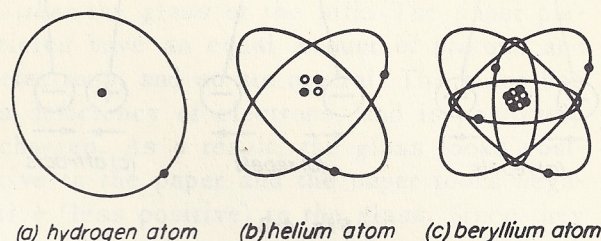


Fig. 4-2

neutrons. Also, note that two of the electrons have orbits of one diameter and two electrons have orbits of a larger diameter. Two electrons in the larger orbits are farther from the nucleus than are the other, inner electrons. Electrons travel at fixed distances from the nucleus. All electrons traveling at the same distance from the nucleus have orbits of the same diameter, and are said to be in the same *shell* or *ring*. In the innermost shell, there is room for only two electrons. If an atom contains more than two electrons, a second shell is formed. This shell may have as many as eight electrons. Thus, in the first two shells, an atom may have as many as ten electrons; two in the first shell and eight in the second. If there are more than ten electrons, a third shell is formed, and so on. The third shell may contain as many as eighteen electrons, the fourth shell as many as thirty-two, and the fifth shell as many as fifty.

4.3. LAW OF CHARGES

All electrons are exactly alike and all protons are alike, no matter whether they are from an atom of hydrogen or an atom of gold. They all obey one of the basic laws of electricity: *Like charges repel each other, and unlike charges attract each other.* This means that electrons repel each other, protons repel each other, and electrons and protons attract each other. This is shown in Fig. 4-3.

When an atom loses one or more electrons, the protons of the nucleus seek to attract other electrons to balance their positive charge. Under normal conditions, atoms tend to have equal positive and negative charges and to be electrically neutral.

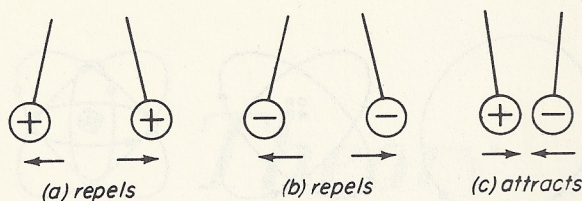


Fig. 4-3

4.4. ELECTRIC CURRENT

Under certain conditions, an atom can be forced to take more than a normal amount of electrons. When this happens, the atom tends to pass its excess electrons to some nearby atom. The electrons that it passes on are not necessarily those it gets. Figure 4-4 shows a possible path of electrons passing from atom to atom in a piece of carbon. Assume that electron *A* has just attached itself to atom 1. Normally, a carbon atom has four electrons in its outer shell; this one now has five. It therefore passes electron *B* to atom 2. Atom 2 in turn, passes electron *C* to atom 3, and so on. This transfer of electrons is practically instantaneous and continues until some atom gets rid of the excess as a *free* electron or until an atom which has a deficiency of electrons receives it. This movement of electrons from atom to atom is what we call *electric current*. We will study more about it later.

Free Electrons. Most electrons remain permanently in their atoms. In some materials however, one or more of the electrons in the outermost shell are loosely attached. With very little pressure applied to them, they may be detached from their atoms and become *free electrons*. In fact, in some materials electrons exist as free electrons even before

any pressure is applied. Such metals as silver and copper have many free electrons. Glass, rubber, mica, and some other substances, on the other hand, have very few free electrons. Naturally, electricity will flow more easily when it is easy to move electrons. This helps to explain why certain metals conduct electricity more readily than others.

Conductors and Non-Conductors. Electric current depends upon the movement of electrons. Copper and silver, because of their many free electrons, are frequently used to conduct electricity. We call them good conductors of electricity, or say that they have high *conductivity*. Copper is more commonly used than silver because it is cheaper and almost as efficient a conductor. In radio and television, we often need materials that do *not* conduct electricity well. Such materials are called *non-conductors*, or *insulators*. An insulator is a substance that is a relatively poor conductor of electricity. Materials such as glass, mica, polystyrene, and rubber have so few free electrons that they make poor conductors but excellent insulators. Figure 4-5 shows some insulators.

No known substance is a perfect insulator — one that passes no electrons, regardless of applied pressure. Every insulating material is good only to a certain point, depending upon the material. When the applied pressure is high enough, any insulator breaks down.

4.5. STATIC ELECTRICITY

Thus far, we have mentioned only electricity in motion, or current. However, there

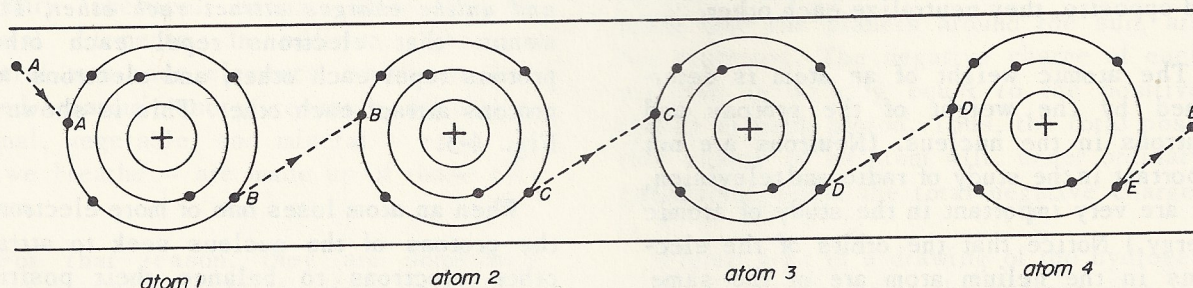


Fig. 4-4

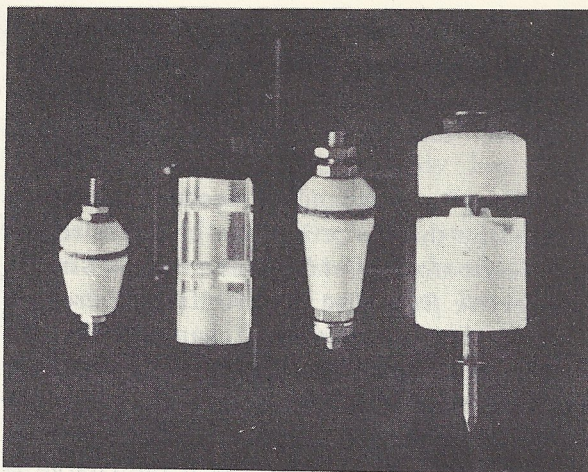


Fig. 4-5

is another kind with which you are probably familiar. It is called *static electricity*, which means electricity at rest. At times, when you comb your hair, you produce a charge of electricity on the comb. You can prove that it is there by using the charged comb to attract small bits of paper. A driver who slides out of his car from a nylon-covered seat may develop a charge on his body, which he discharges when he touches the ground or the handle of the car door. Until he touches the ground or the door handle, the charge on his body is static electricity. When he touches the ground or handle, electrons start moving and current results.

Suppose we rub a piece of glass with a piece of silk. The rubbing produces friction between the two surfaces, and electrons are wiped from the glass to the silk. The glass is left with a deficiency of electrons, and the silk with an excess of electrons. We say that the glass is positively charged and the silk is negatively charged. Since the number of electrons removed from the glass equals the number received by the silk, the two bodies are equally and oppositely charged. If we place their surfaces together again, the electrons eventually return to the glass from the silk. Charged bodies always seek to regain equilibrium or neutrality. All that is needed is a conducting path.

If we give a glass rod a positive charge by rubbing it with a silk cloth, we can attract small particles, such as paper, with

either the glass or the silk. The paper particles have an equal amount of protons and electrons, and so are neutral. The glass has a deficiency of electrons, and is positively charged. As a result, the glass looks positive to the paper and the paper looks negative (less positive) to the glass. Since they are unlike, they attract each other. In much the same way, the silk looks negative to the paper and the paper looks positive (less negative) to the silk. Since they are unlike, they also attract each other.

If we suspend a positively charged glass rod, as shown in Fig. 4-6a, and bring another positively charged rod near it, the glass rod will turn away, as shown by the arrow. Having like charges, the rods repel each other. If, however, the positively charged rod is approached by a negatively charged rod, the two will attract each other, as shown in Fig. 4-6b, since unlike charges attract. The force of attraction decreases as the distance between the charges increases, and increases as the distance between them decreases. In other words, the nearer they are to each other, the greater is the force that is exerted.

We normally show the field surrounding the charged body by lines, as shown in Fig. 4-6c, d, and e. We call these *lines of force*, and we show them leaving a negatively charged body. The direction is the same as that which would be travelled by a negative charge if it were placed in the electric field between two unlike charges. These lines of force do not actually exist, but they give us a convenient way of showing the force and the direction of an electric field of force.

In later lessons, you will learn more about electric fields and will discover how important they are to your study of radio and TV theory.

4-6. ELECTRIC FIELD

If during a football game, the ball should suddenly take off and sail over the goal posts, you would know that it took force acting upon the ball to send it over the posts. It would not

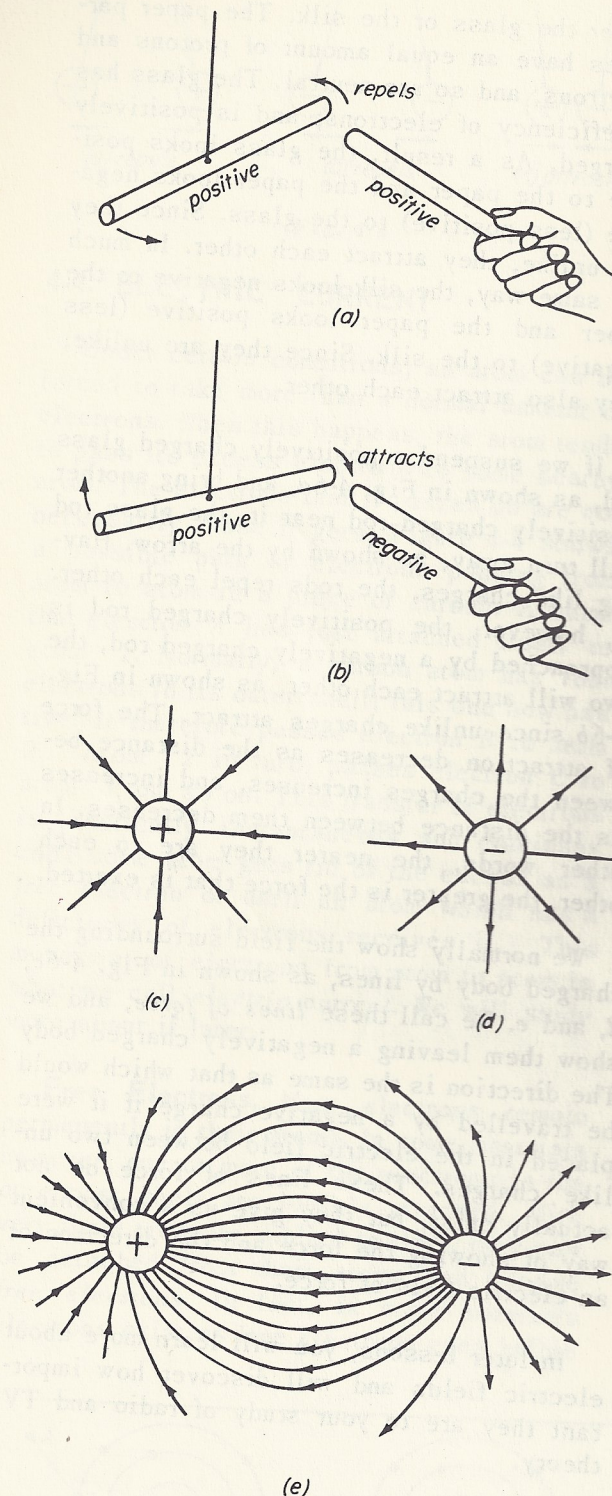


Fig. 4-6

matter that you might not have seen somebody's foot or arm send the ball on its way; you would know that the ball could not take off by itself. In much the same way, the fact that two charged bodies have an effect upon

each other — that they can attract without actually touching each other — that there must be some force acting on them, even though we cannot actually

The region surrounding a charged body is affected by this force. So, we call this the *electrostatic field*, or even more simply, the *electric field*. The electric field, then, is the region surrounding a charged body that is affected by the charge. Any charge that enters the field will be acted upon by this force. For example, an electron entering an electric field will be attracted if the field is positive and will be repelled if the field is negative.

4.7. CURRENT FLOW WITHOUT A CONDUCTOR

Current can flow without a conductor under certain conditions. We can see this in the action of an electron tube. If most of the tube is taken out of a glass tube in which there are two electrodes — a filament and a plate — and the filament is heated sufficiently, the filament gives off electrons. If the plate is positively charged, electrons will flow from the filament to the plate without a conductor. This is shown in Figure 4-7. The action of the batteries in producing these charges will be studied later in the course.

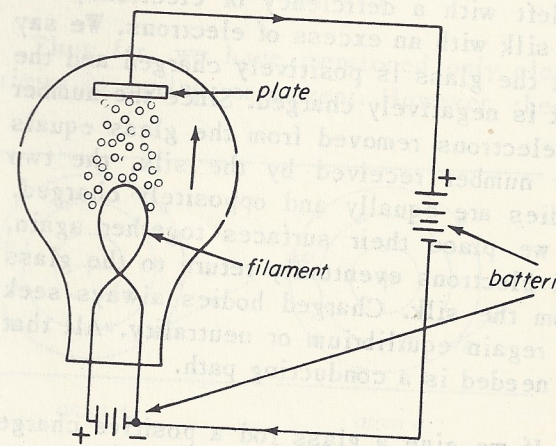


Fig. 4-7

4-8. DIRECTION OF CURRENT FLOW

We have learned that when a body has a deficiency of electrons, it is said to be positively charged. When a body has an excess of electrons, it is said to be negatively charged. If we permit the positively charged body to touch the negatively charged body, or if we place a conductor between them, electrons will travel from the negatively charged body to the positively charged body. Such a flow of electrons is called a current. The flow of electrons is always from negative to positive. Figure 4-8 shows a lamp connected to a battery. The positive terminal of the battery is marked with a plus (+) sign and the negative terminal is marked with a minus (-) sign. The arrows show that the electrons will flow from the negative terminal of the battery, through the lamp, to the positive terminal of the battery. (In the battery, something similar to the electron flow occurs from the positive terminal to the negative terminal, but this is a special condition. In all outside circuits, the electrons flow from negative to positive.)

Before the electron theory was developed, however, scientists believed that current flow in the circuit was from the positive terminal of the battery to the negative terminal, and from negative to positive within the battery. This current flow is referred to as the *conventional* current flow. For many years, servicemen have been following this theory in tracing circuits, and many books have been written using this older idea of current flow. However, as long as we remember that *electrons* flow from negative to positive, we shouldn't become confused.

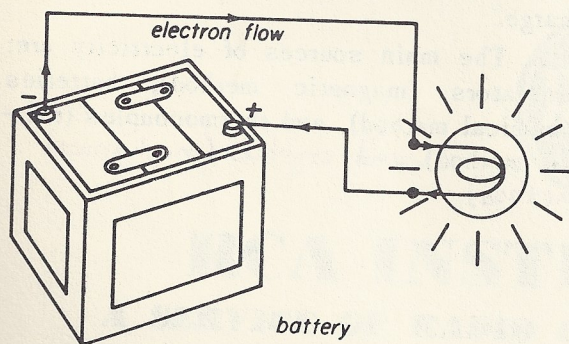


Fig. 4-8

4-9. DIFFERENCE IN POTENTIAL

When a difference in charge exists between two bodies, a force or pressure tends to equalize the charge between them. That is, when an excess of electrons exists, the electrons try to flow toward some point where there are fewer electrons. The force that tends to make electrons travel through a conductor toward a positive charge is called *emf* (electromotive force), potential difference, or voltage. No matter what it is called, it is electrical pressure. The unit of electrical pressure is the *volt*. An exact definition of the volt is given in Theory Lesson 5.

4-10. SOURCES OF ELECTRICITY

While we can produce an electrical charge by rubbing glass with silk, or by rubbing hard rubber with fur, it would be difficult to produce large quantities of electricity by such methods. Three practical methods for producing electricity in quantity are: chemical, magnetic, and thermal, and *mechanical*.

The *chemical* method (see Fig. 4-9a) is used in both "dry" and "wet" batteries. In either case, two different metals, such as copper and zinc, or nickel and iron, are placed in a container containing a solution called an *electrolyte*. When a conductor is connected to the battery terminals, a difference in potential is produced, which results in a current flow. (How batteries work is the subject of Theory Lesson 5.) Because batteries are a rather expensive source of electricity, their use in radio usually is limited to portable equipment, such as portable radios, hearing aids, portable amplifiers, etc.

The *magnetic* method of producing electricity (see Fig. 4-9b) is used in generators. These are driven by gasoline or diesel engines, steam turbines, water wheels, or windmills. This way of producing electricity is the most economical and widely used. Generators are discussed in Theory Lesson 12.

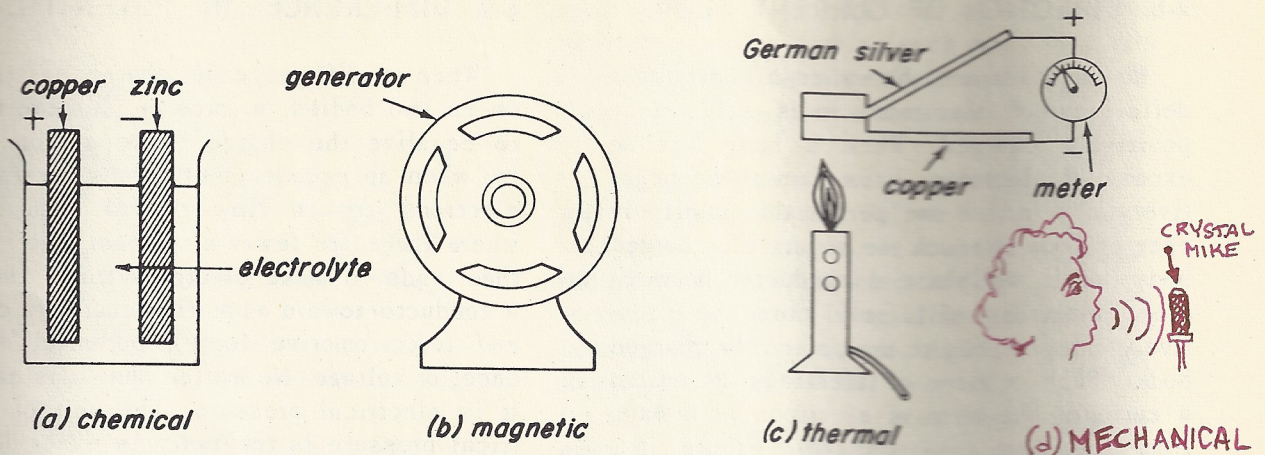


Fig. 4-9

Producing electricity by the *thermal* method requires the use of two different metals. Figure 4-9c shows two metals, German silver and copper, joined together. The other ends are shown connected to a meter. When heat is applied to the point at which the metals are joined, a difference in potential is produced at the other ends, and the meter will show that a current is flowing. Such a device is called a thermocouple. The amount of voltage produced by this method depends upon the metals used and the heat applied. Usually, only small amounts of electricity are produced. The chief application of the thermal method is in the measurement of high-frequency currents and the measurement of very high temperatures. However, during World War II many people in Britain used a thermocouple device heated by charcoal or wood to generate electricity for their radios. In this way, even when electric power plants were bombed, they could still operate their radios.

4-11. SUMMARY

To understand the lessons to come, you must know and remember the following things:

1. Atoms, in their normal state, have as many protons as electrons and are therefore electrically neutral.

2. Some metals, particularly silver and copper, have many free electrons and are therefore good conductors of electricity.

3. Other materials, such as glass, mica, and rubber, have few free electrons and are therefore good insulators.

4. The law of charges states that like charges repel each other and unlike charges attract each other.

5. A positively charged body is one that has a deficiency of electrons (fewer electrons than protons).

6. A negatively charged body is one that has an excess of electrons (more electrons than protons).

7. When a difference in potential exists in a battery or a generator or between two charged bodies, and a conducting path completes the circuit, an electric current will flow. This means that the electrons will drift toward the positive (or less negative) charge.

8. The main sources of electricity are: generators (magnetic method), batteries (chemical method), and thermocouples (thermal method). *and crystals (mechanical method)*